E.O. Lawrence Berkeley National Laboratory
Environment, Health, and Safety Division
Environmental Services Group

United States Department of Energy

US Department of Energy

Radionuclide Air Emission Annual Report

(Subpart H of 40 CFR 61)

Calendar Year 2001

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FACILITY INFORMATION

1.1 SITE DESCRIPTION

1.1.1 Laboratory Operations

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is a multi-program national laboratory managed by the University of California (UC) for the U.S. Department of Energy (DOE). Berkeley Lab's major role is to conduct basic and applied research in biology, physics, chemistry, materials, and energy. Berkeley Lab, the birthplace of the cyclotron, was founded by the late Nobel laureate, Ernest Orlando Lawrence, in 1931.

Berkeley Lab operates facilities encompassing areas where radionuclides are handled and stored that are subject to the U.S. Environmental Protection Agency (EPA) radioactive air emission regulations in 40 CFR Part 61, Subpart H, "National Emission Standard for Hazardous Airborne Pollutants other than Radon from DOE Facilities" (NESHAPs). Figure 1 illustrates the Berkeley Lab general site configuration and locations of buildings.

Radiochemical and radiobiological studies performed at Berkeley Lab typically use millicurie[1] quantities of a variety of radionuclides. All use of radionuclides at Berkeley Lab must be authorized by a written authorization or permit. A radiation work authorization is issued for long-term projects under routine radiological conditions; a radiation work permit is issued for nonresearch projects or tasks that require radiation protection measures. Each authorization or permit is reviewed at least annually, depending on changes to the project. An authorization or permit establishes the location of radioactive material areas (work areas where unsealed radioactive material is handled) and radioactive material storage areas (controlled areas where radioactive material is stored only, with no direct manipulation of the material). Table 1 identifies buildings at Berkeley Lab where handling of unsealed radioactive material is authorized.

[1] One millicurie is equal to 3.7×10^7 Becquerel (Bq).

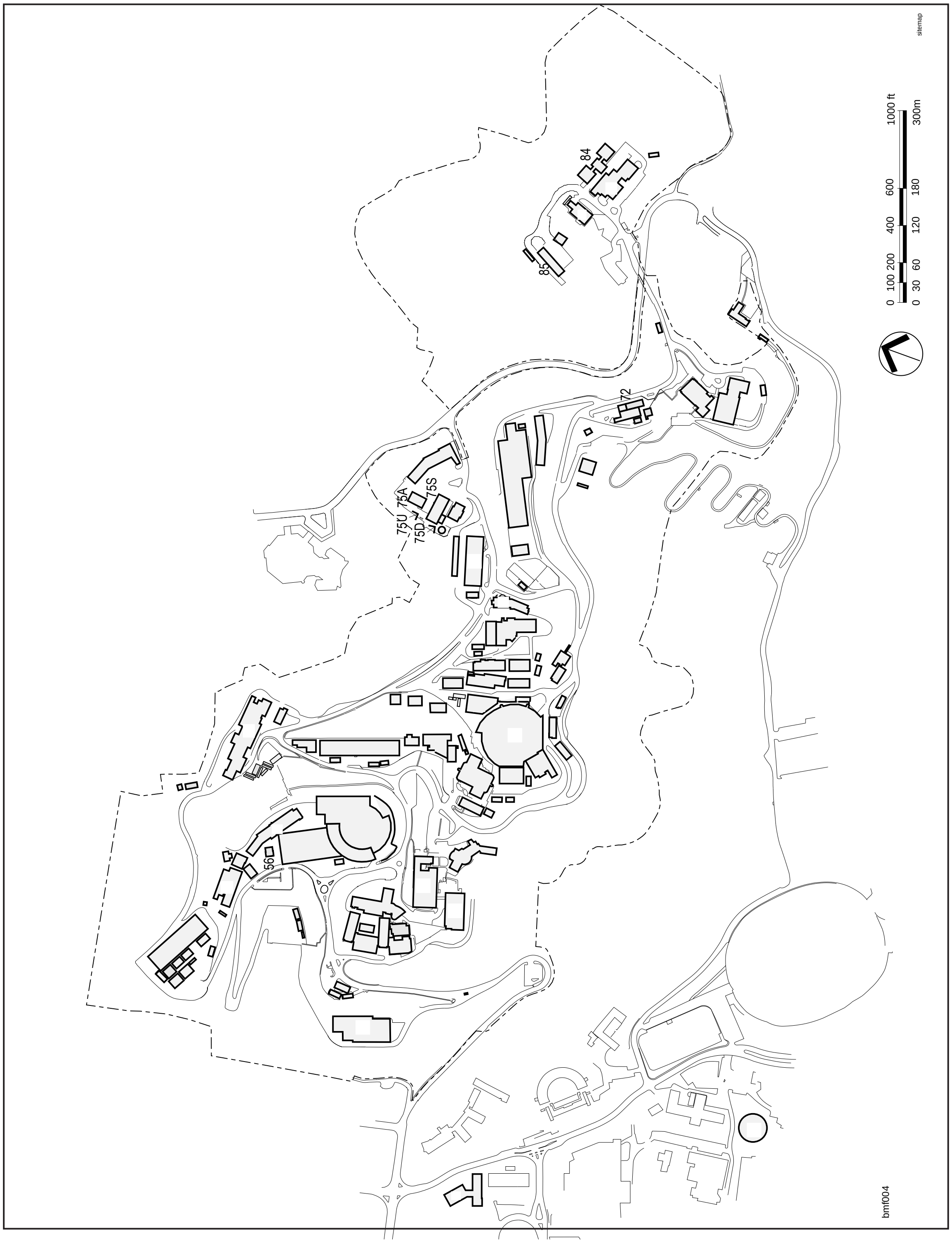

Figure 1. Berkeley Lab Buildings

Table 1. Berkeley Lab Buildings Where Radionuclide Use is Authorized

Building Number	Building Description or Function
1	Donner Laboratory
3	Melvin Calvin Laboratory
6	Advanced Light Source (ALS)
26	Radioanalytical Laboratory
55	Center for Functional Imaging and Life Sciences Research
56	Biomedical Isotope Facility
64	Life Sciences Research
70	Environmental Energy Technology and Nuclear and Earth Sciences Research
70A	Nuclear, Chemical, and Life Sciences Research
71	Heavy Ion Linear Accelerator (HILAC)/Instrument Calibration
72	Low-Background Facility
74	Life Sciences Research
75	National Tritium Labeling Facility (NTLF)
75A	Old Hazardous Waste Facility
76	Radioanalytical Laboratory
83	Life Sciences Research
84	Human Genome Facility
85	Hazardous Waste Handling Facility
88	88-Inch Cyclotron

1.1.2 Berkeley Lab Site

Berkeley Lab is situated on a hillside above the main campus of UC Berkeley. The 80-hectare (200-acre) site is located on the west and southwest-facing slope of the Berkeley hills, at elevations ranging from 150 to 330 m (500 to 1,100 ft) above sea level within the cities of Berkeley and Oakland. It is located about 5 km (3 miles) east of San Francisco Bay and about 25 km (15 miles) east of the city of San Francisco (Figure 2).

Berkeley Lab is located in an urban/wildland interface zone on land owned by the university. Berkeley Lab is surrounded by university land on nearly all sides. In addition, Berkeley Lab maintains a landscape buffer zone between its facilities and the site boundary. Beyond the northern boundary of Berkeley Lab are university facilities and single-family homes, and beyond the western boundary are multiunit dwellings, student residence halls, and commercial buildings. The area to the east and south, which is part of the university's lands, is maintained in a largely natural state and includes recreational facilities and the UC Botanical Garden. The nearest farm is in Wildcat Canyon Regional Preserve, about 3.2 km (2 miles) north of Berkeley Lab, where cattle graze.

Although the population within 80 km (50 miles) of Berkeley Lab increased by about 20% during the 1970s and 1980s from 5 to 6 million, populations declined in Berkeley (population 102,743) and Oakland (population 399,484), the two cities immediately adjacent to Berkeley Lab. Changes in population statistics from the 1990 census have not produced significant differences in dose. Population statistics from the 2000 census data were not yet available at the time of preparation of this report.

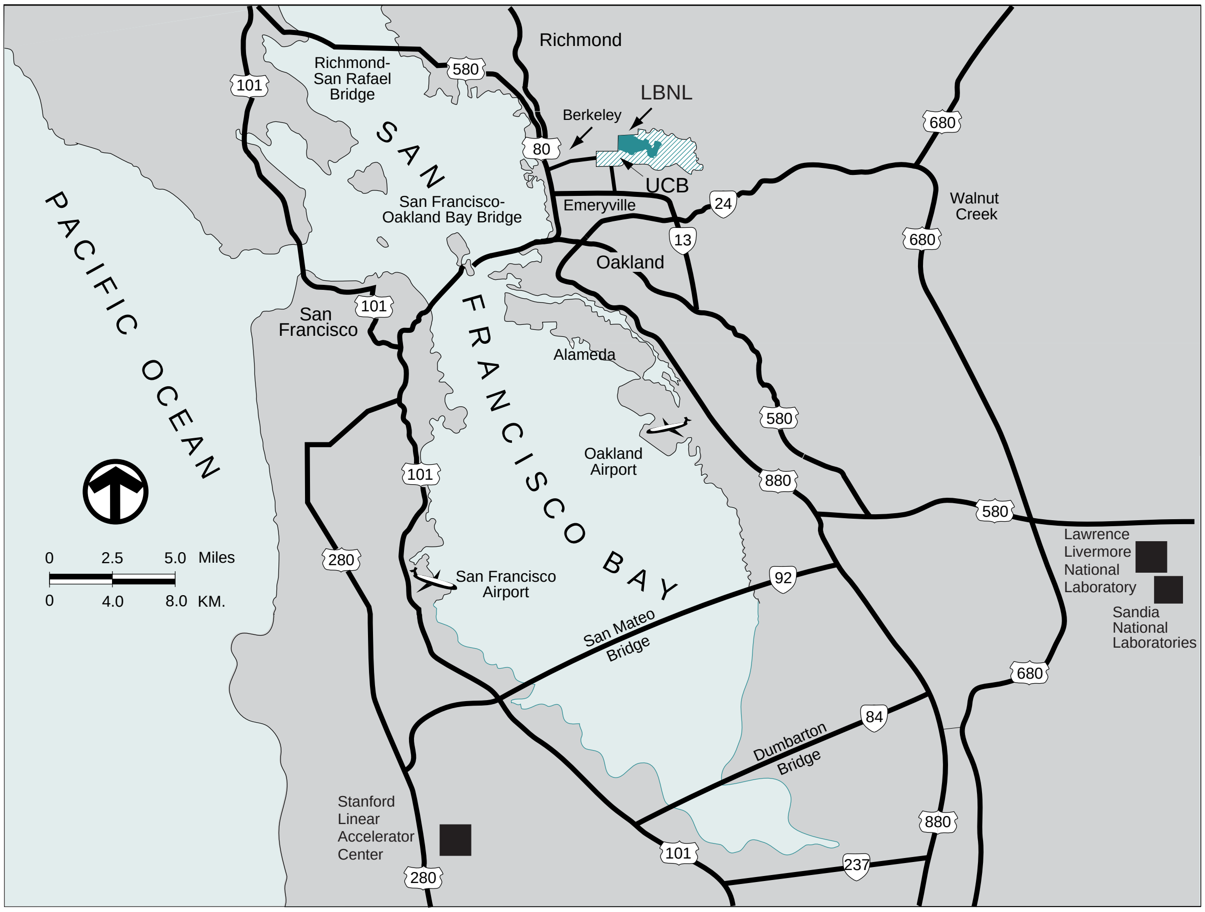

Figure 2. San Francisco Bay Area Map

1.1.3 The Climate at Berkeley Lab

The climate of the Berkeley Lab site is greatly influenced by its proximity to the Pacific Ocean and its exposure to the maritime air that flows in from San Francisco Bay. Seasonal temperature variations are small, with approximate mean temperatures of 17 °C (63 °F) during the summer and 9 °C (48 °F) during the winter. The site's proximity to San Francisco Bay and the Pacific Ocean also keeps the humidity relatively high. The average annual rainfall is about 74 cm (29 in.). About 95% of the rainfall occurs from October through April, and intensities are seldom greater than 1.3 cm/h (0.5 in./h). Thunderstorms, hail, and snow are extremely rare. Winds are usually light, but summer sea breezes can reach up to 9—13 m/s (20—30 mph). Winds from winter storms can reach speeds of 13—18 m/s (30—40 mph). The predominant wind directions are westerly and northwesterly during fair weather and southeasterly in advance of storms.

1.2 COMPLIANCE STATUS OF BERKELEY LAB

Berkeley Lab has been in full compliance with the requirements of 40 CFR, Part 61, Subpart H, since 1995. In 1983, EPA issued a finding of violation that Berkeley Lab had not properly evaluated all release points. Subsequently, EPA and DOE entered into a federal facilities compliance agreement (FFCA) that included a schedule to achieve compliance. In November 1995, EPA sent DOE written confirmation that Berkeley Lab had satisfactorily completed all requirements of the FFCA.

As part of the FFCA, Berkeley Lab formalized all phases of its NESHAPs program and proposed a graded strategy for performing emissions measurements required by Section 61.93(b)(4)(i) of the NESHAPs regulations. Measurement categories are determined by the potential dose from airborne radionuclide emissions (discussed below). Table 2 summarizes the EPA-approved NESHAPs compliance strategy for emissions measurements that Berkeley Lab has followed since the beginning of 1995 and lists the number of potential release points in each measurement category in 2001.

1.3 SOURCE DESCRIPTION

Berkeley Lab uses a wide variety of radionuclides in its radiochemical and biomedical research programs. In addition, radioactive materials are a by-product of charged-particle accelerator operations. Radioactive gases produced by accelerator operations in Buildings 6, 56, and 88 are mainly short-lived radionuclides such as ^{11}C, ^{13}N, and ^{15}O.

All radionuclides that are authorized for use or storage at Berkeley Lab are considered when evaluating the potential for airborne radionuclide emissions. A list of these authorized radionuclides is maintained in the NESHAPs files. As required by 40 CFR, Part 61, no credit is taken for emission controls, such as filters and other devices that prevent radionuclides from being emitted into the air, when evaluating potential to emit airborne radionuclides. In 2001, 24 stacks at 22 facilities at Berkeley Lab had the potential to emit radionuclides into the atmosphere at a level that required measurement under the criteria in Table 2. The potential release points that these stacks exhaust are listed in Table 3, along with the measurement categories of these facilities in 2001.

Based on historical operations, maximum authorized quantities, and emissions measurements, one release point met Category I requirements in 2001: the National Tritium Labeling Facility (NTLF) in Building 75. All other Berkeley Lab areas that were operational in 2001 were small sources; that is, the effective dose equivalent from each potential release point was less than 0.1 mrem/y (1.0×10^{-3} mSv/y), the threshold limit for Category I. Small sources (Category II through IV) were continuously sampled with weekly or monthly analysis of the samples. All Category IV sources were measured using the more rigorous Category III requirements.

Table 2. Summary of NESHAPs Compliance Strategy for Measuring Emissions in 2001

Annual Effective Dose Equivalent (EDE) [mrem/y]	Category	Requirements	Number of Potential Release Points
EDE $\geq$ 10.0	Non-compliant	Reduction or relocation of source term and reevaluation prior to authorization.	0
$10.0 > \text{EDE} \geq 1.0 \times 10^{-1}$	I	• Continuous sampling or monitoring. • Telemetry for nuclides with half-lives < 100 h • EPA application to construct or modify.	1
$1.0 \times 10^{-1} > \text{EDE} \geq 5.0 \times 10^{-2}$	II	Continuous sampling with weekly analysis.	10
$5.0 \times 10^{-2} > \text{EDE} \geq 1.0 \times 10^{-2}$	III	Continuous sampling with monthly analysis.	13
$1.0 \times 10^{-2} > \text{EDE} \geq 1.0 \times 10^{-3}$	IV	Sampling annually during project activity.	0
$\text{EDE} < 1.0 \times 10^{-3}$	V	Inventory controlled by radiation work authorization/permit (RWA/RWP) and periodic evaluation. No monitoring required.	115

To determine the annual dose from airborne emissions, the full set of authorized radionuclides was reviewed, and a subset was developed that includes radionuclides that were potentially used (received or measured) in 2001 (Table 4), depending upon the measurement category.

As discussed above, potential release points in categories I through IV were sampled or monitored. Potential release points in Category V were, in general, not sampled or monitored. Instead, Berkeley Lab evaluated the effective dose equivalent from Category V potential release points by assuming that all radionuclides received during the year were emitted, whether they were actually used or not. This provides a conservative, upper-bound estimate of the annual emissions. The total number of Category V potential release points in 2001 (115) is based on the number of areas where radionuclides were authorized. All radioactive material areas were included in this category, regardless of whether radionuclides were actually used there in 2001. This also provides a conservative, upper-bound estimate of the impact of radioactive airborne emissions. Two area sources of potential fugitive emissions identified in 2001 were also determined to be Category V.

Note that in calculating effective dose equivalent, Berkeley Lab conservatively assumed that the high-risk alpha-emitting radionuclide, ^{232}Th, and the high-risk beta-emitting radionuclide, ^{90}Sr, were responsible for gross alpha and gross beta measurements, respectively. This provides an

Table 3. Facilities with Potential to Emit Airborne Radionuclides in 2001

Facilities with Potential Release Points	NESHAPs Compliance Strategy Category					
	Category I	Category II	Category III	Category IV[a]	Category V	Total
1	0	0	3	0	8	11
3	0	0	0	0	2	2
6	0	0	0	0	6	6
26	0	0	0	0	3	3
55	0	0	1	0	10	11
56	0	2	0	0	0	2
64	0	0	0	0	1	1
70	0	2	2	0	9	13
70A	0	1	5	0	26	32
71	0	0	0	0	5	5
72	0	0	0	0	1	1
74	0	0	0	0	15	15
75	1	1	0	0	4	6
75A	0	0	0	0	1	1
75S	0	0	1	0	0	1
75U	0	0	0	0	1	1
75 Sump	0	0	0	0	1	1
76	0	0	0	0	1	1
83	0	0	0	0	3	3
84	0	0	0	0	11	11
85	0	2	0	0	0	2
88	0	2	1	0	7	10
Total	**1**	**10**	**13**	**0**	**115**	**139**

[a] All Category IV sources were measured using the more rigorous Category III requirements.

Table 4. Radionuclides Potentially Used (Received or Measured) In 2001

Radionuclide	Atomic Number	Symbol	Principal Radiation Types	Energy (MeV)	Half-Life
Antimony	51	^{122}Sb	beta	1.414	2.7 days
				1.980	
			gamma	0.564	
		^{124}Sb	beta	0.610	60.2 days
				2.301	
			gamma	0.603	
				1.691	
Bromine	35	^{82}Br	beta	0.444	1.5 days
			gamma	0.777	
				0.554	
				0.619	
Calcium	20	^{45}Ca	beta	0.258	162.7 days
Carbon	6	^{11}C	positron/gamma	0.511	20.5 minutes
		^{14}C	beta	0.156	5730 years
Cerium	58	^{141}Ce	beta	0.436	32.5 days
				0.581	
			gamma	0.145	
Cesium	55	^{134}Cs	beta	0.658	2.1 years
			gamma	0.605	
				0.796	

Table 4. Radionuclides Potentially Used (Received or Measured) In 2001 (continued)

Radionuclide	Atomic Number	Symbol	Principal Radiation Types	Energy (MeV)	Half-Life
Cobalt	27	^{57}Co	gamma	0.122	272 days
		^{60}Co	beta	0.318	5.3 years
			gamma	1.33	
Europium	63	^{152}Eu	beta	0.699	13.5 years
			gamma	0.122	
				0.344	
				1.408	
Fluorine	9	^{18}F	positron/gamma	0.511	109.7 minutes
Gadolinium	64	^{153}Gd	gamma	0.097	241.6 days
Germanium	32	^{71}Ge	x-ray	0.010	11.4 days
Hydrogen (Tritium)	1	^{3}H	beta	0.0186	12.3 years
Iodine	53	^{123}I	gamma	0.159	13.2 hours
		^{125}I	gamma	0.035	59.4 days
		^{131}I	beta	0.606	8.0 days
			gamma	0.364	
Iron	26	^{59}Fe	beta	0.466	44.5 days
			gamma	1.099	
				1.292	
Nitrogen	7	^{13}N	positron/gamma	0.511	10.0 minutes
Niobium	41	^{95}Nb	beta	0.160	35.0 days
			gamma	0.766	
Oxygen	8	^{15}O	positron/gamma	0.511	122 seconds
Phosphorus	15	^{32}P	beta	1.71	14.3 days
Protactinium	91	^{233}Pa	beta	0.256	27 days
			gamma	0.312	
Rubidium	37	^{86}Rb	beta	1.77	18.7 days
			gamma	1.08	
Ruthenium	44	^{103}Ru	beta	0.223	39.3 days
			gamma	0.497	
Scandium	21	^{46}Sc	beta	0.357	83.8 days
			gamma	1.121	
				0.889	
Sodium	11	^{24}Na	beta	1.391	15.0 hours
			gamma	1.369	
				2.754	
Strontium	38	^{90}Sr	beta	0.546	28.8 years
Sulfur	16	^{35}S	beta	0.167	87.2 days
Technetium	43	^{99m}Tc	gamma	0.141	6.0 hours
Thallium	201	^{201}Tl	gamma	0.167	3.0 days
Thorium	90	^{229}Th	alpha	4.85	7.3×10^{3} years
		^{232}Th	alpha	4.01	1.4×10^{10} years
Tin	50	^{113}Sn	gamma	0.392	115.1 days
Uranium	92	^{233}U	alpha	4.82	1.59×10^{5} years
		^{238}U	alpha	4.20	4.47×10^{9} years
Ytterbium	70	^{175}Yb	beta	0.466	4.2 days

upper-bound estimate of the effective dose equivalent. Note also that actual measured amounts were used, in accordance with DOE guidance,[1] even when the measured amount was less than the analytical laboratory's minimum detectable activity or negative. This may result in discrepancies with other Berkeley Lab reports, such as the annual site environmental report, that treat less-than-detectable results differently. Of the radionuclides listed in Table 4, only a few radionuclides account for nearly all of the activity emitted: ^{3}H, ^{18}F, and ^{11}C.

Many Berkeley Lab potential release points can be grouped.[2] The following grouping criteria were used.

- The sum of the effective dose equivalent attributable to all stacks in the group must be less than 0.1 mrem (1×10^{-3} mSv).
- Release points must be in close proximity (in the same or a nearby building), with similar operations and similar nuclides used in the facilities.
- Release points grouped in the description section may not be grouped in the dose assessment section if the critical receptors are not the same.

Using this grouping scheme, Berkeley Lab identified 15 NESHAPs sources (Table 5). For each source, Berkeley Lab used the EPA-approved atmospheric dispersion dose calculation computer code CAP88-PC to estimate the effective dose equivalent to an off-site maximally exposed individual (MEI). The fifteen CAP88-PC computer model assessments were performed separately to simulate eight point sources, five grouped sources, and two area sources for dose assessment in 2001. The remainder of this section will discuss the results of these assessments.

Table 5. NESHAPs Point, Group, and Area Sources In 2001

NESHAPs Sources	Type of Source	Location
Building 1	Point	UC Berkeley Campus
Building 6	Point	Main Site
Building 3	Point	UC Berkeley Campus
Buildings 26 and 76	Group	Main Site
Buildings 55, 56, and 64	Group	Main Site
Buildings 70 and 70A	Group	Main Site
Building 71	Point	Main Site
Building 72	Point	Main Site
Buildings 74, 83, and 84	Group	Main Site
Building 75	Point	Main Site
Buildings 75A and 75S	Group	Main Site
Building 75U	Area	Main Site
Building 75 Sump	Area	Main Site
Building 85	Point	Main Site
Building 88	Point	Main Site

[1] Department of Energy. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T, Washington, D.C. (January 1991).
[2] Department of Energy. "Guidance for the Preparation of the 1992 Radionuclide Air Emissions Annual Report under Subpart H of 40 CFR Part 61," DOE memorandum (1993).

As identified in Figure 1, Buildings 1 and 3 are located outside of Berkeley Lab's main perimeter and could be considered separate facilities since they are not on one contiguous site. However, Building 1 and Building 3 are located on the adjacent UC Berkeley campus and are within walking distance of the main Berkeley Lab site. Annual radioactive air emissions from these off-site buildings and the associated effective dose equivalent at each local receptor are several orders of magnitude lower than the highest building emissions and doses at the main Berkeley Lab site. Thus, it would be inappropriate and misleading to model and report these much lower doses separately. Therefore, for reporting and dose-modeling purposes, all of these off-site buildings will be considered as being on one contiguous Berkeley Lab site.

1.3.1 Building 1 (Donner Laboratory)

Scientists at Donner Laboratory conduct research in nuclear medicine through the use of new chemical probes and new instrumentation for applications to aging, atherosclerosis, and cancer. The building is located at the eastern edge of the UC Berkeley campus. The predominant nuclides used are ^{14}C, ^{3}H, ^{125}I, ^{32}P, and ^{35}S as labeled amino acids and DNA precursors. Many UC Berkeley campus employees share this building for various other research activities. Work is mostly done on bench tops and in hoods. Emissions are from building vents and hoods. In 2001, many of these potential release points were classified as Category V, for which the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. Three stacks in Building 1 were sampled and analyzed monthly for ^{125}I, ^{14}C, gross alpha, gross beta, and tritium. For conservatism in estimating the dose, alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 6.

Table 6. Building 1 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
9	10	ESE	UC Berkeley	^{14}C	1.61×10^{-4}	3.6×10^{-6}	0.1
				^{3}H	4.99×10^{-4}	1.6×10^{-6}	0.1
				^{125}I	2.52×10^{-4}	2.9×10^{-3}	86.7
				^{32}P	2.10×10^{-5}	4.1×10^{-6}	0.1
				^{35}S	1.38×10^{-4}	5.6×10^{-6}	0.1
				Gross alpha[d]	7.87×10^{-8}	4.2×10^{-4}	12.7
				Gross beta[e]	3.60×10^{-7}	4.7×10^{-6}	0.1
					Total	$\mathbf{3.3 \times 10^{-3}}$	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Assumed to be ^{232}Th
[e] Assumed to be ^{90}Sr

1.3.2 Building 3 (Calvin Laboratory)

The Calvin Laboratory conducts basic research on the dynamics of living cells and on the interaction of radiant energy with organic matter. The laboratory has made significant contributions to our understanding of the molecular mechanisms of photosynthesis and of the effects of environmental pollutants on plant and animal cells. Cell and molecular biology studies are performed in this laboratory. As with Building 1, this building is located in the eastern portion of the UC Berkeley campus. The predominant radionuclides used are ^{14}C, ^{32}P, and ^{35}S as labeled amino acids and DNA precursors. Building 3 is occupied by Berkeley Lab personnel and by UC Berkeley personnel. Work is done on bench tops and in hoods. Emissions are from building vents and hoods. In 2001, potential release points in Building 3 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 7.

Table 7. Building 3 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
15	60	S	Residence and business	^{14}C	5.00×10^{-9}	2.6×10^{-10}	0.1
				^{32}P	5.00×10^{-7}	6.4×10^{-8}	26.5
				^{35}S	6.00×10^{-6}	1.8×10^{-7}	73.4
					Total	$\mathbf{2.4 \times 10^{-7}}$	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.3 Building 6 (Advanced Light Source)

The Advanced Light Source (ALS) in Building 6 is the world's brightest synchrotron radiation source in the extreme ultraviolet and soft x-ray regions of the spectrum. The ALS is a national user facility open to qualified scientists and engineers in a broad range of disciplines. The ALS injector produces neutrons during its operation, which activate the air in the injector vault. Because the ALS is a low-power accelerator, compared to Berkeley Lab's other accelerators such as the 88-Inch Cyclotron, its generation of air activation products is substantially lower. The maximum potential annual emissions of ^{13}N and ^{15}O (the most significant air activation products) are computed to be 1.8×10^{-5} Ci (6.5×10^{5} Bq) and 9.4×10^{-8} Ci (3.5×10^{3} Bq), respectively.[1]

Other radionuclides may be considered a source of emissions at the ALS. In 2001, these included ^{238}U, which was received for use in spectroscopy experiments.

[1] Donahue, R. "Air Activation in the ALS Storage Ring," Health Physics Note #191, Lawrence Berkeley National Laboratory, Berkeley, CA (April 8, 1991).

Potential release points in Building 6 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 8.

Table 8. Building 6 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
20	370	NE	UC Lawrence Hall of Science	^{13}N	1.80×10^{-5}	8.0×10^{-9}	0.1
				^{15}O	9.40×10^{-8}	2.4×10^{-11}	< 0.1
				^{238}U[d]	2.10×10^{-8}	1.0×10^{-5}	99.9
					Total	**1.0×10^{-5}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Includes progeny

1.3.4 Buildings 26 and 76 (Radioanalytical Laboratories)

In these buildings, low-activity radiochemical analyses of bioassay samples, environmental samples, and hazardous waste are performed by Berkeley Lab. In addition, Building 76 has some counter calibration sources. Trace quantities of radionuclides are used in sample spiking and standards preparation. Emissions are from building vents and hoods. In 2001, potential release points within Buildings 26 and 76 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 9.

Table 9. Building 26/76 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Description	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
8	240	N	UC Lawrence Hall of Science	^{35}S	5.40×10^{-8}	2.5×10^{-9}	< 0.1
				^{125}I	1.00×10^{-6}	1.6×10^{-5}	72.9
				^{131}I	1.00×10^{-6}	6.0×10^{-6}	27.1
					Total	**2.2×10^{-5}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.5 Buildings 55, 56, and 64 (Center for Functional Imaging, Biomedical Isotope Facility, and Life Sciences Research)

At Building 56, the Biomedical Isotope Facility develops radiopharmaceuticals and advanced medical imaging technologies including positron emission tomography (PET), single photon emission computed tomography (SPECT), and nuclear magnetic resonance imaging (MRI) and applies them to the study of atherosclerosis, heart disease, aging, neurological and psychiatric diseases, and cancer. Building 56 houses a small accelerator that produces ^{18}F, ^{11}C, and ^{13}N for positron emission tomography and other experimental studies. In addition, in collaboration with the 88-Inch Cyclotron, the Building 56 accelerator is also used to produce isotopes of carbon, nitrogen, fluorine, and oxygen for the Berkeley Experiments with Accelerated Radioactive Species (BEARS) Project. Thus, airborne emissions from Building 56 are limited to positron emitters. In 2001, two stacks on Building 56 were continuously monitored for positron emitters using real-time radiation detectors. For dose calculations, all positron emissions were assumed to be ^{18}F. Fluorine-18 is an appropriate surrogate for radioisotopes of carbon, nitrogen, and oxygen because it has metabolic and radiological properties that are similar to the other radionuclides and presents the greatest risk, resulting in a cautious overestimate of the effective dose equivalent. In addition, annual ^{18}F emissions are overestimated because falsely positive results occur when radionuclides absorb onto the real-time detectors, causing measurements that can’t be correlated with laboratory activities. These false positives were included in the annual ^{18}F emissions.

At Building 55, the primary radiological activities carried out by life sciences researchers are positron emission tomography using ^{18}F and metabolic studies using ^{125}I. Other projects include a gene therapy study and work with ^{32}P to determine the metabolic fate of DNA-based imaging agents. Work with radioiodine is done in a fume hood that is fitted with a high-efficiency particulate air (HEPA) filter and a tetraethylene diamine (TEDA)-doped carbon filter. In 2001, one stack on Building 55 was sampled and analyzed monthly for ^{125}I, gross alpha, and gross beta. For conservatism in estimating the dose, alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr, respectively.

In Building 64, life sciences researchers use ^{32}P to label probes for DNA analysis. In 2001, the potential release point in Building 64 was classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 10.

Table 10. Building 55/56/64 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
9	250	N	Residence	^{57}Co	1.00×10^{-6}	3.8×10^{-7}	< 0.1
				^{153}Gd	1.00×10^{-7}	1.4×10^{-8}	< 0.1
				^{3}H	1.44×10^{-4}	1.6×10^{-7}	< 0.1
				^{123}I	2.50×10^{-4}	3.8×10^{-6}	< 0.1
				^{125}I	1.65×10^{-4}	6.8×10^{-4}	6.8
				^{131}I	2.00×10^{-6}	3.0×10^{-6}	< 0.1
				^{95}Nb	1.50×10^{-6}	4.8×10^{-7}	< 0.1
				^{32}P	2.25×10^{-6}	1.4×10^{-7}	< 0.1
				^{103}Ru	1.50×10^{-6}	3.5×10^{-7}	< 0.1
				^{113}Sn	1.00×10^{-6}	1.4×10^{-7}	< 0.1
				^{99m}Tc	3.50×10^{-5}	3.2×10^{-8}	< 0.1
				^{201}Tl	3.30×10^{-6}	3.5×10^{-8}	< 0.1
				Positron emitters[d]	2.20×10^{0}	9.3×10^{-3}	92.9
				Gross alpha[e]	9.01×10^{-9}	1.7×10^{-5}	0.2
				Gross beta[f]	1.72×10^{-7}	7.3×10^{-7}	< 0.1
					Total	**1.0×10^{-2}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Assumed to be ^{18}F, although some of the activity may be due to lower risk radioisotopes of carbon, nitrogen, and oxygen
[e] Assumed to be ^{232}Th
[f] Assumed to be ^{90}Sr

1.3.6 Buildings 70 and 70A (Nuclear, Chemical, Life, and Earth Sciences and Environmental Energy Technology)

Nuclear Science Division programs include research in nuclear structure and reactions, relativistic nuclear collisions, nuclear and particle astrophysics, nuclear data evaluation, and nuclear theory. Chemical Sciences Division conducts research in the areas of chemical physics and the dynamics of chemical reactions, the structure and reactivity of transient species, electron spectroscopy, surface chemistry and catalysis, electrochemistry, chemistry of the actinide elements and their relationship to environmental and physiological issues, and atomic physics. Life Sciences Division programs include studies of tumor cells, DNA damage from radiation, and impacts of cosmic radiation exposure to astronauts. Earth Sciences Division and Environmental Energy Technology programs perform fundamental and applied research related to energy and environmental resources.

Programs carried out in these facilities include super-heavy nuclear studies, waste migration research using tracer amounts of radionuclides, nuclear chemistry experiments, analysis of activated geological samples, and radiation biology research. Research activities using radioactive material are carried out by various research groups in 33 of the many small laboratories within Buildings 70 and 70A. In 2001, 35 potential release points in Buildings 70 and 70A were classified as Category V and the remaining 10 potential release points were sampled continuously and analyzed weekly or monthly. In addition, one stack on Building 70A was monitored for alpha-emitting radionuclides with a real-time, continuous air monitor. Sampled radionuclides include ^{125}I, ^{14}C, gross alpha, gross beta, and tritium. For conservatism in estimating the dose, alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 11.

Table 11. Building 70/70A Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
13	330	W	UC Berkeley dormitory	^{14}C	4.95×10^{-5}	3.0×10^{-7}	0.1
				^{59}Fe	2.52×10^{-6}	2.8×10^{-7}	0.1
				^{3}H	7.36×10^{-5}	1.8×10^{-8}	< 0.1
				^{32}P	6.04×10^{-6}	8.7×10^{-8}	< 0.1
				^{35}S	2.00×10^{-6}	6.2×10^{-9}	< 0.1
				^{229}Th	2.69×10^{-10}	2.0×10^{-7}	0.1
				^{233}U	9.00×10^{-12}	1.3×10^{-9}	< 0.1
				^{238}U[d]	8.01×10^{-9}	5.1×10^{-6}	2.1
				^{233}Pa	2.23×10^{-9}	5.5×10^{-11}	< 0.1
				^{152}Eu	1.78×10^{-9}	1.3×10^{-8}	< 0.1
				^{134}Cs	9.20×10^{-10}	2.1×10^{-9}	< 0.1
				^{175}Yb	1.29×10^{-9}	8.1×10^{-11}	< 0.1
				^{46}Sc	8.82×10^{-7}	3.0×10^{-7}	< 0.1
				^{86}Rb	1.26×10^{-7}	2.7×10^{-9}	< 0.1
				^{60}Co	2.24×10^{-9}	1.6×10^{-8}	< 0.1
				^{24}Na	1.03×10^{-9}	8.7×10^{-12}	< 0.1
				^{141}Ce	1.58×10^{-9}	2.7×10^{-11}	< 0.1
				^{125}I	2.35×10^{-8}	2.2×10^{-8}	< 0.1
				^{45}Ca	7.11×10^{-9}	2.4×10^{-9}	< 0.1
				^{122}Sb	1.25×10^{-10}	2.9×10^{-11}	< 0.1
				^{124}Sb	7.22×10^{-10}	1.7×10^{-10}	< 0.1
				^{232}Th and gross alpha[e]	6.08×10^{-7}	2.3×10^{-4}	96.3
				Gross beta[f]	2.96×10^{-6}	2.9×10^{-6}	1.2
					Total	$\mathbf{2.4 \times 10^{-4}}$	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Includes progeny, as appropriate
[e] Assumed to be ^{232}Th
[f] Assumed to be ^{90}Sr

1.3.7 Building 71 (Heavy Ion Linear Accelerator)

The Heavy Ion Linear Accelerator (HILAC) is no longer in operation; however, in 2001 the building was used for radiation instrument calibration and service. This operation involves the use of small quantities (nanocurie amounts) of tritium gas. Other projects in Building 71 in 2001 included the Spallation Neutron Source and the laser-driven accelerator of the Laser Optics and Accelerator Systems Integrated Studies (l'OASIS) Group, small accelerators operating at voltages that would not produce air activation products. In 2001, potential release points in Building 71 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 12.

Table 12. Building 71 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
13	180	N	Residence	^{3}H	1.00×10^{-4}	1.6×10^{-7}	100
					Total	**1.6×10^{-7}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.8. Building 72 (Low-Background Facility)

The Low-Background Facility in Building 72 is used to perform gamma spectroscopy to characterize low-level radioactive material in support of low-activity materials certification, studies in cosmic ray and neutron activation, nuclear science experiments, and environmental health and safety activities. In 2001, potential release points in Building 72 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 13.

Table 13. Building 72 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
6	750	SSW	UC Berkeley	^{24}Na	1.00×10^{-12}	6.4×10^{-15}	14.8
				^{82}Br	5.00×10^{-12}	3.7×10^{-14}	85.2
					Total	**4.3×10^{-14}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.9 Buildings 74, 83, and 84 (Human Genome Facility and Life Sciences)

Research in these buildings includes a wide variety of cell biology, virology, research medicine, and genomics projects. The Human Genome Center of Berkeley Lab is oriented almost exclusively toward developing and implementing methods for cost-effective and accurate high-throughput human DNA sequencing. Emissions from Building 74 come from hoods and stacks that vent individual workplaces. Buildings 83 and 84 vent through HEPA-filtered biological cabinets. When research activities involve ^{125}I, they are normally carried out in TEDA-doped activated-carbon-filtered enclosures (note, however, that no radioactive iodine was received in 2001). In 2001, potential release points in Buildings 74, 83, and 84 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic evaluations. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 14.

Table 14. Buildings 74/83/84 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
7	120	S	UC Berkeley	^{14}C	1.00×10^{-7}	8.0×10^{-9}	< 0.1
				^{3}H	2.34×10^{-5}	8.7×10^{-8}	0.3
				^{32}P	1.63×10^{-4}	3.2×10^{-5}	97.3
				^{35}S	2.30×10^{-5}	8.0×10^{-7}	2.4
					Total	$\mathbf{3.3 \times 10^{-5}}$	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.10 Building 75 (National Tritium Labeling Facility)

Since 1982, the National Tritium Labeling Facility (NTLF) has been a designated DOE national user facility engaged in tritium-labeling research and development. The facility was mainly used for activities in which a wide variety of molecules were labeled with tritium and purified for further use in chemical, biochemical, and radiopharmaceutical studies. In fall 2001, the National Institutes of Health cancelled its funding of the NTLF. The facility ceased labeling operations in December 2001 and reduced its tritium inventory by 90%. Subsequently, closure activities began, which ultimately include removal of radioactive material, dismantling and disposition of equipment, and decontamination and decommissioning of the laboratories, outdoor facilities, and ancillary spaces.

There are two stacks associated with NTLF activities. In 2001, real-time monitoring was performed continuously on one stack and continuous sampling with subsequent laboratory analysis was performed on both. Emissions are in the form of gaseous tritium (about 27% of the total) and tritiated water (about 73% of the total). Gaseous tritium emissions were quantified as tritiated water even though their impacts are about 1/25,000 of those of comparable emissions of tritiated water, resulting in a very conservative overestimate of dose.

Approximately 90% of tritium emissions at Berkeley Lab come from the stack located on the northern hillside near Building 75. This stack is the closest discharge point to the off-site maximally exposed individual located at the UC Lawrence Hall of Science, 110 m northwest of Building 75. The other discharge point from the Building 75 roof is farther from the UC Lawrence Hall of Science.

For many years, Berkeley Lab overestimated the dose to the maximally exposed individual by not taking into account the momentum effect of effluent velocity (that is, stack effluent exit velocity was set to zero) in the CAP88-PC computer model. As recommended by EPA,[1] starting in 1998 Berkeley Lab began including the momentum effect (that is, the actual stack effluent exit velocity was applied) in the CAP88-PC computer model to more closely reflect the physical conditions of the hillside stack exhaust. In 2001, the effluent exit velocity and stack diameter of each of the two NTLF stacks was also taken into account, although both are conservatively assumed to be at the location of the hillside stack, which is closest to the UC Lawrence Hall of Science.

Building 75 is the only source at Berkeley Lab that historically resulted in more than 1% of the NESHAPs effective dose equivalent standard of 10 mrem/y. There was no unplanned release from the NTLF in 2001. For reporting purposes, the maximally exposed individual for this source was also identified as the maximally exposed individual for the entire Berkeley Lab site in 2001. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 15.

Table 15. Building 75 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Description	Radionuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
8.5	110	NW	UC Lawrence Hall of Science	^{3}H	1.88×10^{1}	4.2×10^{-2}	100
6.7	110	NW		^{3}H	1.38×10^{0}		
					Total	**4.2×10^{-2}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.11 Buildings 75A and 75S (Old Hazardous Waste Handing Facility and Storage Locker)

In 1997, Berkeley Lab's Hazardous Waste Handling Facility in Buildings 75A and part of Building 75 (Room 127) was moved to its present location at Building 85, and the areas it had occupied in Buildings 75A and 75-127 were decontaminated and decommissioned. In 2001, a HEPA-filtered enclosure in Building 75A was used for radiological characterization of large items in preparation for recycling, reuse, and repackaging. The sampling system temporarily installed on the enclosure stack was used to collect alpha- and beta-emitting radionuclides. The HEPA-filtered enclosure was dismantled in December 2001 and stack sampling was discontinued. Building 75S is a storage locker used to hold tritium-contaminated waste until it is shipped for disposal. For conservatism in estimating the dose, alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent from Building 75A and 75S is presented in Table 16.

Table 16. Building 75A/S Source Characteristics and Dose Impacts

[1] Rosenblum, S., and R. Lessler (EPA). Telephone conversation with S. Black (DOE), and R. Pauer, L. Wahl, M. Ruggieri (LBNL) (May 15, 2002).

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Description	Radionuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
8	150	NW	UC Lawrence Hall of Science	^3H	1.47×10^{-2}	1.9×10^{-4}	0.4
				Gross alpha[d]	1.41×10^{-8}	3.0×10^{-4}	61.3
				Gross beta[e]	4.57×10^{-8}	1.9×10^{-6}	38.3
					Total	**4.9×10^{-4}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Assumed to be ^{232}Th
[e] Assumed to be ^{90}Sr

1.3.12 Building 75U (Storage Container)

In 2001, a radiation work permit was prepared for removing items potentially contaminated with tritium stored in a sea-land container (75U). Low-level tritium contamination was identified in water on the floor of the container, and it was determined that the container could potentially represent a Category V fugitive source of tritium emissions. The container was unloaded, decontaminated, and prepared for removal from Berkeley Lab. A summary of the CAP88-PC source term input parameters and effective dose equivalent from Building 75U is presented in Table 17.

Table 17. Building 75U Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Description	Radionuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
0	130	NW	UC Lawrence Hall of Science	^3H	5.70×10^{-7}	2.3×10^{-8}	100
					Total	**2.3×10^{-8}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.13 Building 75 Sump

In 2001, a sump north of Building 75 was found to have collected rainwater and water draining from the Building 75 stack located on the hillside north of Building 75. Low-level tritium contamination was measured in the sump water, and it was determined that the sump could potentially represent a Category V fugitive source of tritium emissions. The sump was drained and filled with concrete, and the drain from the stack was routed to a collection container. To estimate the annual emission, all the water in the sump (which contained 0.5 mCi of tritium) was assumed to have evaporated during the year. This is a very conservative assumption that overestimates the annual emission. A summary of the CAP88-PC source term input parameters and effective dose equivalent from Building 75 sump is presented in Table 18.

Table 18. Building 75 Sump Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
0	130	NW	UC Lawrence Hall of Science	^{3}H	5.00×10^{-4}	2.1×10^{-5}	100
					Total	**2.1×10^{-5}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{2} mSv

1.3.14 Building 85 (New Hazardous Waste Handing Facility)

Berkeley Lab waste operations moved to the newly constructed Hazardous Waste Handling Facility at Building 85 in mid-1997. In 2001, this building had two stacks equipped with continuous air sampling systems to collect alpha- and beta-emitting radionuclides, ^{14}C, ^{125}I, and tritium. For conservatism in estimating the dose, alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent from Building 85 is presented in Table 19.

Table 19. Building 85 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
7	120	S	UC Berkeley	^{14}C	7.44×10^{-4}	2.0×10^{-5}	7.3
				^{3}H	1.32×10^{-2}	1.6×10^{-5}	5.9
				^{125}I	1.58×10^{-6}	6.5×10^{-6}	2.4
				Gross alpha[d]	1.09×10^{-7}	2.3×10^{-4}	0.5
				Gross beta[e]	3.36×10^{-7}	1.4×10^{-6}	84.0
					Total	**2.7×10^{-4}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Assumed to be ^{232}Th
[e] Assumed to be ^{90}Sr

1.3.15 Building 88 (88-Inch Cyclotron)

The cyclotron accelerates beams from hydrogen to uranium in support of national programs in nuclear science, biology, medicine, and industrial applications. The primary airborne impact to an off-site individual from this facility is attributable to short-lived air activation radionuclides (mostly positron emitters) produced in the cyclotron vault during the fraction of the beam year when intense light ions are accelerated. In 2001, positron emissions (primarily from isotopes of carbon, nitrogen, and oxygen) were measured directly using a real-time monitoring system. Small amounts of actinides and other radionuclides in targets are used in experimental caves, fume hoods, and glove boxes. Emissions in 2001 were estimated based on radionuclide receipts and emissions from two stacks that were sampled for alpha- and beta-emitting radionuclides. For conservatism in estimating the dose, all positron emitters from this facility were assumed to be ^{11}C, and alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr, respectively. Carbon-11 is an appropriate surrogate for radioisotopes of nitrogen and oxygen because it has metabolic and radiological properties that are similar to the other radionuclides and presents the greatest risk, resulting in a cautious overestimate of the effective dose equivalent. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 20.

Table 20. Building 88 Source Characteristics and Dose Impacts

Release Height (m)	Local MEI[a] Distance (m)	Local MEI Dir.	Local MEI Descrip-tion	Radio-nuclide	Annual Emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of Total Dose (%)
12	110	W	Residence	Positron emitters[d]	4.68×10^{-1}	4.2×10^{-4}	86.7
				^{71}Ge	8.17×10^{-3}	1.8×10^{-5}	0.1
				^{238}U[e]	1.80×10^{-10}	1.5×10^{-7}	< 0.1
				Gross alpha[r]	9.28×10^{-8}	4.6×10^{-5}	9.6
				Gross beta[g]	3.43×10^{-7}	4.6×10^{-7}	3.7
					Total	**4.8×10^{-4}**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Assumed to be ^{11}C
[e] Includes progeny
[f] Assumed to be ^{232}Th
[g] Assumed to be ^{90}Sr

AIR EMISSIONS DATA

Source and emission control information are summarized in Table 21.

Table 21. Sources and Emission Controls In 2001

Source	Number of Potential Release Points	Type of Control	Efficiency (%)	Distance to Nearest Receptor
Point Sources				
Building 1	11	None[a]	NA[b]	10 m (classrooms in same building)
Building 3	2	None[a]	NA	60 m (workplace)
Building 6	6	None[f]	NA	370 m (UC Lawrence Hall of Science)
Building 71	5	None	NA	220 m (UC Lawrence Hall of Science)
Building 72	1	None	NA	750 m (UC Berkeley)
Building 75 (NTLF)	6	Silica Gel[c] Molecular Sieve[c] Bubbler	>99 >99 >99	110 m (UC Lawrence Hall of Science)
Building 85	2	HEPA[d] TEDA-DAC[e]	>99 >75	120 m (UC Berkeley)
Building 88	10	HEPA TEDA-DAC	>99 >75	110 m (Residence)
Grouped Sources				
Buildings 26/76	4	HEPA	>99	240 m (UC Lawrence Hall of Science)
Buildings 55/56/64	14	HEPA TEDA-DAC[g]	>99 >75	170 m (Residence)
Buildings 70/70A	45	HEPA None[h]	>99 NA	330 m (UC Berkeley Dormitory)
Buildings 74/83/84	28	TEDA-DAC None	>75 NA	120 m (UC Berkeley)
Buildings 75A/75S	2	HEPA None	> 75	150 m (UC Lawrence Hall of Science)
Area Sources				
Building 75U	1	None[i]	NA	130 m (UC Lawrence Hall of Science)
Building 75 Sump	1	None[i]	NA	130 m (UC Lawrence Hall of Science)

[a] Emissions are from Berkeley Lab fume hoods, which do not require filtration for the small radionuclide amounts used.
[b] Not applicable
[c] Silica gel and molecular sieve traps are more than 99% efficient for trapping tritiated water vapor when they are changed before breakthrough. Research personnel regularly change traps when working in the facility.
[d] High-efficiency particulate air
[e] Tetraethylene diamine (TEDA)-doped activated carbon traps
[f] Radionuclides emitted from accelerators are short-lived air activation products, for which emission control is impractical.
[g] TEDA-DAC filters at Building 55 only
[h] Stacks included in this group source vent a number of laboratories whose research employs microcurie and millicurie quantities (between 3.7×10^4 and 3.7×10^7 Bq) of a number of actinides. The most conservative dose-equivalent representative of the actinides was used.
[i] Potential fugitive source having no emission controls

Quantities of radionuclides potentially emitted from Berkeley Lab sources in 2001 are presented in Table 22. These data were used to calculate the collective population dose for 2001.

Table 22. Airborne Radioactivity Potentially Emitted In 2001

Radionuclide	Potential Activity Emitted (Ci/y)	Potential Activity Emitted (Bq/y)	Total Potential Activity (%)
^{3}H	2.02×10^{1}	7.47×10^{11}	88.3
^{18}F	2.20×10^{0}	8.15×10^{10}	9.6
^{11}C	4.68×10^{-1}	1.73×10^{10}	2.1
^{71}Ge	8.17×10^{-3}	3.02×10^{8}	< 0.1
^{14}C	8.43×10^{-4}	3.12×10^{7}	< 0.1
^{125}I	4.20×10^{-4}	1.55×10^{7}	< 0.1
^{123}I	2.50×10^{-4}	9.25×10^{6}	< 0.1
^{32}P	1.93×10^{-4}	7.13×10^{6}	< 0.1
^{35}S	1.69×10^{-4}	6.26×10^{6}	< 0.1
^{99m}Tc	3.50×10^{-5}	1.30×10^{6}	< 0.1
^{13}N	1.80×10^{-5}	6.66×10^{5}	< 0.1
Beta (^{90}Sr)	4.17×10^{-6}	1.54×10^{5}	< 0.1
^{201}Tl	3.30×10^{-6}	1.22×10^{5}	< 0.1
^{131}I	3.00×10^{-6}	1.11×10^{5}	< 0.1
^{59}Fe	2.52×10^{-6}	9.31×10^{4}	< 0.1
^{103}Ru	1.50×10^{-6}	5.55×10^{4}	< 0.1
^{95}Nb	1.50×10^{-6}	5.55×10^{4}	< 0.1
^{57}Co	1.00×10^{-6}	3.70×10^{4}	< 0.1
^{113}Sn	1.00×10^{-6}	3.70×10^{4}	< 0.1
Alpha (^{232}Th)	8.98×10^{-7}	3.32×10^{4}	< 0.1
^{46}Sc	8.82×10^{-7}	3.26×10^{4}	< 0.1
^{86}Rb	1.26×10^{-7}	4.68×10^{3}	< 0.1
^{153}Gd	1.00×10^{-7}	3.70×10^{3}	< 0.1
^{15}O	9.40×10^{-8}	3.48×10^{3}	< 0.1
^{238}U	2.90×10^{-8}	1.07×10^{3}	< 0.1
^{45}Ca	7.11×10^{-9}	2.63×10^{2}	< 0.1
^{24}Na	1.00×10^{-9}	3.70×10^{1}	< 0.1
^{60}Co	2.24×10^{-9}	8.29×10^{1}	< 0.1
^{233}Pa	2.23×10^{-9}	8.25×10^{1}	< 0.1
^{152}Eu	1.78×10^{-9}	6.59×10^{1}	< 0.1
^{141}Ce	1.58×10^{-9}	5.85×10^{1}	< 0.1
^{175}Yb	1.29×10^{-9}	4.77×10^{1}	< 0.1
^{134}Cs	9.20×10^{-10}	3.40×10^{1}	< 0.1
^{124}Sb	7.22×10^{-10}	2.67×10^{1}	< 0.1
^{229}Th	2.69×10^{-10}	9.95×10^{0}	< 0.1
^{122}Sb	1.25×10^{-10}	4.68×10^{0}	< 0.1
^{233}U	9.00×10^{-12}	3.33×10^{-1}	< 0.1
^{82}Br	5.00×10^{-12}	1.85×10^{-1}	< 0.1
Total	$\mathbf{2.29 \times 10^{1}}$	$\mathbf{8.47 \times 10^{11}}$	**100%**

3

DOSE ASSESSMENTS

3.1 DESCRIPTION OF DOSE MODEL

To meet DOE guidance, the EPA atmospheric dispersion and radiation dose calculation computer code, CAP88-PC version 1.0, was used to calculate the effective dose equivalent to an individual within each population segment at various distances and from various release points. A total of 15 CAP88-PC individual runs were executed to model the 15 point, group, and area sources described in Section I. As discussed previously, the NTLF in Building 75 was identified as the major release point at Berkeley Lab. Therefore, the maximally exposed individual associated with this facility was also specified (with appropriate distances and directions) in each of the 15 individual CAP88-PC runs. The reported effective dose equivalent to the maximally exposed individual at Berkeley Lab includes contributions from all 15 CAP88-PC models (Table 23).

Collective population dose is calculated as the average radiation dose to an individual in a specified area, multiplied by the number of individuals in that area. This population dose assessment was performed with two population runs using CAP88-PC. These CAP88-PC runs were based on the input parameters from the Building 75 individual run, with the source term replaced by all the radionuclides listed in Table 22. One run included all radionuclides in Table 22 except ^{238}U; the second run included ^{238}U and progeny, assumed to be in equilibrium. The results of the two runs were summed. A summary of the collective dose assessment attributed to each potentially emitted radionuclide is given in Table 24.

3.2 SUMMARY OF INPUT PARAMETERS

The 2001 radioactive air emissions were either measured or conservatively derived based on the inventory received during the year and are shown in Table 22 in Section II.

Berkeley Lab used on-site meteorological data for performing dose assessments. Berkeley Lab began collecting this data in early 1994 at a 20-m tower located in the central portion of the Laboratory. The 2001 meterological data is maintained in the NESHAPs files.

Table 23. Summary of Dose Assessment from All Berkeley Lab Sources

			Relative to the Specified Building				Relative to the MEI[a] of Building 75			
Building Number	Building Name/Function	Release Height (m)	Local MEI Distance (m)]	Local MEI Dir.	Local MEI Description	Local MEI Dose (mrem/y)[b]	Bldg 75 Distance (m)	Bldg 75 MEI Dir.	Bldg 75 MEI Dose (mrem/y)	% Total Dose[c]
1	Donner Laboratory at UC Berkeley	9	10	ESE	UC Berkeley	3.3×10^{-3}	980	ENE	3.4×10^{-3}	6.0
3	Calvin Lab at UC Berkeley	15	60	S	Residence and Business	2.4×10^{-7}	1070	NE	2.3×10^{-7}	< 0.1
6	Advanced Material Lab/Advanced Light Source	20	370	NE	UC Lawrence Hall of Science	1.0×10^{-5}	370	NE	1.0×10^{-5}	< 0.1
26/76	Radioanalytical Lab	8	240	N	UC Lawrence Hall of Science	2.2×10^{-5}	240	N	2.2×10^{-5}	< 0.1
55/56/64	Center for Functional Imaging/Biomedical Isotope Facility/Life Sciences	9	250	N	Residence	1.0×10^{-2}	440	E	9.1×10^{-3}	16.3
70/70A	Nuclear/Chemical/Life/ Earth/Environmental Sciences	13	330	W	UC Berkeley Dormitory	2.4×10^{-4}	510	NE	1.9×10^{-4}	0.3
71	Heavy Ion Linear Accelerator/Instrument Calibration	13	180	N	Residence	1.6×10^{-7}	220	E	2.3×10^{-7}	< 0.1
72	Low-Background Facility	6	750	SSE	UC Berkeley	4.3×10^{-14}	540	NW	3.1×10^{-13}	< 0.1
74/83/84	Human Genome Facility/Life Sciences	7	120	S	UC Berkeley	3.3×10^{-5}	730	WNW	3.4×10^{-5}	< 0.1
75	National Tritium Labeling Facility	8.5	110	NW	UC Lawrence Hall of Science	4.2×10^{-2}	110	NW	4.2×10^{-2}	75.1
75A/75S	Old Hazardous Waste Facility/Storage Locker	8	150	NW	UC Lawrence Hall of Science	4.9×10^{-4}	150	NW	4.9×10^{-4}	0.9
75U	Storage Container	0	130	NW	UC Lawrence Hall of Science	2.3×10^{-8}	130	NW	2.3×10^{-8}	< 0.1
75 Sump	Sump	0	130	NW	UC Lawrence Hall of Science	2.1×10^{-5}	130	NW	2.1×10^{-5}	< 0.1
85	New Hazardous Waste Handling Facility	7	120	S	UC Berkeley	2.7×10^{-4}	550	WNW	3.8×10^{-4}	0.7
88	88-Inch Cyclotron	12	110	W	Residence	4.8×10^{-4}	670	ENE	2.7×10^{-4}	0.5
								Total	$\mathbf{5.6 \times 10^{-2}}$	**100%**

[a] MEI = maximally exposed individual
[b] 1 mrem = 1.0×10^{-2} mSv
[c] Effective dose equivalent

Table 24. Summary of Collective Dose to the Population within 80 km of Berkeley Lab

Radionuclide	Collective Dose (person-rem/y)[a]	% of Total
^{3}H	3.82×10^{-1}	79.7
^{18}F	6.81×10^{-2}	14.2
^{232}Th	1.92×10^{-2}	4.0
^{11}C	5.56×10^{-3}	1.2
^{125}I	1.83×10^{-3}	0.4
^{238}U	1.03×10^{-3}	0.2
^{71}Ge	8.33×10^{-4}	0.2
^{14}C	3.46×10^{-4}	< 0.1
^{90}Sr	1.55×10^{-4}	< 0.1
^{32}P	1.23×10^{-4}	< 0.1
^{46}Sc	1.88×10^{-5}	< 0.1
^{35}S	1.77×10^{-5}	< 0.1
^{59}Fe	1.72×10^{-5}	< 0.1
^{123}I	1.28×10^{-5}	< 0.1
^{229}Th	1.12×10^{-5}	< 0.1
^{131}I	8.47×10^{-6}	< 0.1
^{95}Nb	5.99×10^{-6}	< 0.1
^{57}Co	5.05×10^{-6}	< 0.1
^{103}Ru	4.44×10^{-6}	< 0.1
^{113}Sn	1.26×10^{-6}	< 0.1
^{60}Co	1.05×10^{-6}	< 0.1
^{152}Eu	8.66×10^{-7}	< 0.1
^{99m}Tc	3.18×10^{-7}	< 0.1
^{45}Ca	1.52×10^{-7}	< 0.1
^{134}Cs	1.34×10^{-7}	< 0.1
^{13}N	1.31×10^{-7}	< 0.1
^{86}Rb	1.28×10^{-7}	< 0.1
^{153}Gd	1.26×10^{-7}	< 0.1
^{233}U	7.14×10^{-8}	< 0.1
^{201}Tl	3.92×10^{-8}	< 0.1
^{124}Sb	1.05×10^{-8}	< 0.1
^{175}Yb	4.90×10^{-9}	< 0.1
^{233}Pa	3.11×10^{-9}	< 0.1
^{122}Sb	1.82×10^{-9}	< 0.1
^{141}Ce	1.48×10^{-9}	< 0.1
^{24}Na	4.67×10^{-10}	< 0.1
^{15}O	2.09×10^{-10}	< 0.1
^{82}Br	3.01×10^{-12}	< 0.1
Total	$\mathbf{4.78 \times 10^{-1}}$	**100%**

[a] 1 person-rem = 1×10^{-2} person-Sv

For all sources, stack heights are shown in Table 23. For all point and grouped sources, except Building 75, other stack input parameters were 0.1 m diameter and 0 m/s exit velocity. At Building 75, input parameters for the hillside stack were 0.91 m diameter and 7.66 m/s exit velocity and for the roof stack were 0.53 m diameter and 5.69 m/s exit velocity. For the area sources, Building 75U input parameters were 15 m^2 area and 0 m/s momentum, and Building 75 sump input parameters were 1 m^2 area and 0 m/s momentum.

3.3 COMPLIANCE ASSESSMENT

This compliance assessment used the computer code CAP88-PC, Version 1.0, to calculate the effective dose equivalent to an off-site, maximally exposed individual. This exposure represents the sum of impacts from all 15 sources modeled to that location (the maximally exposed individual for Building 75). A summary of the dose assessment for each source is presented in Table 23.

Effective dose equivalent:	0.06 mrem/year (6.0E-4 mSv/year)
Location of maximally exposed individual:	UC Lawrence Hall of Science at 110 m northwest of Building 75

3.4 CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein, and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (See, 18 U. S. C. 1001).

Signature:____________________________________Date:____________

David C. McGraw
Division Director, Environment, Health, and Safety

Signature:____________________________________Date:____________

Richard H. Nolan
Director, DOE Berkeley Site Office

4

ADDITIONAL INFORMATION

4.1 ADDITIONS OR MODIFICATIONS

There were no facility additions or modifications in 2001. There were, however, changes in source measurement and reporting in 2001, based primarily on changes in work authorized. Changes from last year's report include the grouping of Building 64 with the Building 55/56 source, changes in emissions measurement at the Building 75 complex, and elimination of on-site Building 2 and off-site Buildings 903 and 934 as potential release points.

4.1.1 Grouping of Building 64

Work with radionuclides was authorized in Building 64, room 235, and radionuclides were received for use there in 2001. This potential release point is Category V and contributes negligible radioactivity to Berkeley Lab's annual air emissions. Building 64 was not reported as a potential release site in the past; however, reporting of this site would not have changed the reported effective dose equivalent from air emissions. In 2001, Building 64 was grouped with Buildings 55 and 56 because the three buildings meet the grouping criteria discussed in "Source Description."

4.1.2 Changes in Emissions Measurements at Building 75 Complex

In 2000, emissions from room 127 of Building 75 and from Building 75C were discussed in the annual report. In 2001, unsealed radionuclides were not used in these locations, so there was no potential to emit airborne radionuclides. These areas were not considered potential release points, and emissions were not measured or calculated in 2001.

In 2001, two area sources of potential fugitive emissions, Building 75U and Building 75 Sump, were identified and determined to be Category V. These sources are discussed further in "Source Description" and below.

Also in 2001, airborne tritium was measured in the room (75D-SEA) where stack samples are processed for shipping to the analytical laboratory. The purpose of air measurements was to determine if samples could be cross contaminated. It was found that room tritium levels were consistent with ambient air tritium levels; that is, levels were about 1/10,000 of stack emissions from the NTLF. There was no indication of sample contamination, so air measurement in this room was discontinued in November 2001.

4.1.3 Elimination of Potential Release Points at Buildings 2, 903, and 934

Radioactive material was not authorized for use in Building 2 in 2001, so it was not considered a potential release point in determining airborne emissions. In addition, as stated in the 2000 *Radionuclide Air Emission Annual Report*, Building 903 no longer contains any radioactive material and Building 934 is no longer occupied by Berkeley Lab researchers, so neither building was considered a potential release point in determining airborne emissions in 2001.

4.2 UNPLANNED RELEASES

There were no unplanned releases in 2001.

4.3 DIFFUSE EMISSIONS

In 2001, two area sources were identified that potentially present a source of fugitive emissions to the maximally exposed individual. One source was 75U, a storage container with low-level tritium contamination. The storage container was decontaminated in 2001 and will not present a source of fugitive emissions in the future. The second source was a sump north of Building 75 collecting rain water and water draining from the stack located in the northern hillside near Building 75. The sump was drained and filled with concrete, and the drain from the stack was routed to a collection container. The drain water will be disposed of and so will not present a source of fugitive emissions in the future. These sources are discussed further in “Source Description.”

SUPPLEMENTAL INFORMATION

5.1 DOSE ESTIMATE

Provide an estimate of collective effective dose equivalent (person-rem/y) for 2001 releases.

The estimated collective effective dose equivalent to persons living within 80 km of Berkeley Lab is 0.5 person-rem (0.005 person-Sv) attributable to 2001 Berkeley Lab airborne emissions (see Table 24).

5.2 RADON EMISSIONS

Provide information on the status of compliance with Subparts Q and T of 40 CFR Part 61, if applicable. Although exempt from Subpart H, provide information on ^{220}Rn emission from sources containing ^{232}U and ^{232}Th where emissions potentially can exceed 0.1 mrem/y (10^{-6} Sv/y) to the public or 10% of the nonradon dose to the public. Provide information on nondisposal/nonstorage sources of ^{222}Rn emissions where emissions potentially can exceed 0.1 mrem/y (10^{-6} Sv/y) to the public or 10% of the nonradon dose to the public.

Subparts Q and T of 40 CFR 61 are not applicable to Berkeley Lab, as the Laboratory does not process, manage, or possess significant enough quantities of uranium mill tailings, ^{226}Ra, ^{232}U, or ^{232}Th, to produce an impact of 0.1 mrem/y (10^{-6} Sv/y) to a member of the public.

5.3 EMISSION POINTS

For the purpose of assessing facility compliance with the NESHAPs effluent monitoring requirements of Subpart H under Section 61.93(b), give the number of emission points subject to the continuous monitoring requirements, the number of these emission points that do not comply with the Section 61.93(b) requirements, and if possible, the cost for upgrades. Describe site periodic confirmatory measurement plans. Indicate the status of the QA program described by Appendix B, Method 114.

Berkeley Lab has identified one source subject to the continuous monitoring requirements of 40 CFR, Subpart H, Section 61.93(b). In 2001, no potential release points produced emissions exceeding 0.1 mrem/y (1.0×10^{-3} mSv/y). The Category I source at Berkeley Lab was the Building 75 (NTLF) hillside stack and the effective dose equivalent to the maximally exposed individual was modeled at 4.2×10^{-2} mrem/y (4.2×10^{-4} mSv/y) for 2001. Berkeley Lab's sampling, monitoring, and analytical methods fully conform to Section 61.93(b) requirements. Berkeley Lab has a) identified all potential release points and evaluated emissions, b) categorized potential release points by effective dose equivalent, and c) suggested suitable measurement methodology for each point. This information was sent to EPA Region IX during 1991 and finalized in 1993.

The program meets or exceeds all provisions contained in Appendix B, Method 114. The current Berkeley Lab *Environmental Monitoring Plan* and Environmental Services Group procedures contain quality assurance elements consistent with Method 114. The Berkeley Lab site-specific NESHAPs *Quality Assurance Project Plan* was originally developed and approved in August 1994 and was most recently revised in November 2001.